A CONCEPT FOR NATURALISTIC DATA COLLECTION FOR VULNERABLE ROAD USERS USING A SMARTPHONE-BASED PLATFORM

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ABSTRACT

This paper presents a smartphone-based platform for large-scale, low-cost, long-term naturalistic data collection aimed at vulnerable road users (VRUs). The approach taken is to collect naturalistic movement data from VRUs based on information from the embedded sensors in high-end smartphones. The Smartphone application, *LogYard*, developed in the current study, allows the recording of high quality data (tri-axial acceleration and rotation at 100 Hz plus GPS position and velocity each second). This way, large data quantities from ATV drivers' movements during daily use in different use cases, can be transferred from a large number of users and accumulated in a cloud-based server for off-line analysis.

Apart from the description on how data is recorded and managed in the smartphone-based platform, also a procedure on how to include participants to studies and how private integrity issues and informed consent can be handled from a distance is presented. By means of the presented smartphone based platform, large number of participants taking part in several parallel on-going studies can be easily administered. This makes the platform a powerful tool to use in large-scale, low-cost, long-term studies providing data from large groups of study participants.

The information made available this way can be used to develop automatic crash notification (ACN) systems directed to VRUs based on identifying movements outside what is "normal" for bicyclists, mopedists, motorcyclists and ATV users.

INTRODUCTION

Almost half of the over 1.2 million deaths in road traffic accidents worldwide each year strike vulnerable road users (VRUs) (WHO, 2009), i.e. pedestrians, bicyclists, moped drivers, and motorcyclists. The typical accident scenario that comes in mind is that the VRU collide with a car. Contrary to such preconceptions, statistics show e.g. that 8 out of 10 bicycle accidents are single vehicle accidents, and that these are often due to bad maintenance or slippery road conditions (Niska and Eriksson, 2013). Single bicycle accidents produce about ¾ of the severe injuries (Niska and Eriksson, 2013) and single accidents account for almost half of the fatalities for motorcyclists (Strandroth and Persson, 2005). An accident with a two-wheel vehicle may, even at fairly low velocities, lead to the driver getting unconscious or in other ways incapable of calling for help, and the accident may stay unnoticed for a long time if happening on small roads or during low traffic.

There is obviously a lot to gain if road users could be equipped with a system or function that not only can detect an accident or emergency situation but also can inform about this by sending an automatic alarm in case the driver is incapable of calling for help. Such an Automatic Crash Notification (ACN) system was first developed for cars by General Motors and installed in their luxury models under the brand name OnStar. Today, OnStar, or similar systems, is installed in millions of vehicles from different manufacturers. These systems automatically send an alarm to a call center in case of a crash triggering the airbag to be deployed. Further development of ACN systems was initiated by US researchers in the late 90s (Champion, et al., 2003), showing that it is possible to use the information available from vehicle sensors such as accelerometers to not only detect crashes but also estimate the severity of the crash and predict how the impact may have affected the passenger(s). In the European Union an ACN initiative is

expected to be introduced in 2018; this service shall work in all member countries and is referred to as *eCall*. Although the *eCall* initiative is first and foremost aimed at automobiles, an adaptation of the system targeting also motorcycles is in progress.

In line with the *eCall* concept for cars, also riders of bicycles, mopeds, motorcycles or all-terrain vehicles (ATVs) can be equipped with sensors that are connected to e.g. a smartphone application (the embedded sensors in the smartphone may be good enough) that triggers an alarm when sudden changes in position or velocity outside what is considered normal for the specific type of vehicle is detected. Although this approach is similar to the *eCall* initiative, it differs significantly as the sensors preferably should be worn by the driver, as it is more relevant to trace what happens to the driver than the vehicle. This approach is further pronounced when considering the opportunity to use GPS information to find not only the site of the accident, but also the exact position of the driver who may be far separated from the vehicle after an accident.

The *Postcrash* group at SAFER foster a general interest in ACN systems and how these can be used to improve the rescueing activities after an accident. Since VRUs is an important group to target in order to reduce road traffic injuries it is highly relevant to extend the current ACN initiatives now starting to be commonly available in automobiles also to other categories of road users.

In order to test the feasibility of an ACN system for VRUs, we performed a pilot study to test the hypothesis that the built-in/embedded sensors of a high-end smartphone can be used to detect a bicycle accident. We found that the smartphone sensors (accelerometers, gyroscopes, and GPS system) can provide information about the movements during bicycling and that a smartphone app can use this information to evaluate falls or crash events in real time (Candefjord, et al., 2014). The study, demonstrated a smartphone app ("jalp!", available from GooglePlay) for detecting bicycle accidents on the Android platform using a Google Nexus 4 smartphone. Although a number of simulated crash situations were used during the development, the main approach was to collect motion data from bicycle use in different situations (on different surfaces, with different bicycles and persons, different placements of the smartphone, on rural roads and in city environments, seated and standing position, etc.). This information was then used to develop an algorithm capable of distinguishing crashes from normal cycling (Candefjord, et al., 2014).

We are now taking this smartphone based ACN concept further by adapating the algorithm for other VRUs. The next in line is ATVs. ATVs have become popular and are commonly used as a light-weight tractor and transportation means in agriculture, forestry, and leisure activities on- and off-road. Unfortunately, the use is associated with a high prevalence of accidents and serious injuries (even fatal). This can be explained by the driver being unprotected, ATVs being heavy (which becomes dangerous if overturning), and, despite the four wheels, having poor driving properties in regular traffic.

As ATV use is more diverse than bicycling we need to learn more about what signifies normal ATV use. In line with the approach taken in the development of the bicycle app described above, extensive data collection can provide a base for what can be considered safe. Movements beyond normal use will then indicate potentially riskful situations that can be used to warn the ATV driver but also send an alarm if an integrated automatic evaluation of all available sensor signals indicate an accident. However, such large-scale collection of naturalistic data to provide a pool of, in this case, "normal ATV use" is generally considered both time consuming and expensive due to the extra mobile equipment needed to follow the driver/vehicle over time. As we use smartphones to detect accidents by means of the developed app for bicycle use, there is just some additional software needed to also record the high-quality accelerometer and gyroscope signals as well as the GPS-information. We have developed the smartphone app "LogYard" (available from Google Play and App Store) that takes the sensor signals from the embedded sensors at 100 Hz, and GPS information every second, and store them for later upload to a cloud-based server.

The aim of this paper is to present a smartphone based platform for low-cost collection of large-scale naturalistic movement data and ways to do this while adhering to established integrity levels for the participating VRUs.

METHODS

Methodological issues relating to large-scale collection of naturalistic movement data from VRUs concerns individual recordings of VRUs activities, ways of contributing additional metadata, and anonymity/privacy.

Recordings of activities

Individual recordings of movement data is performed by means of the developed smartphone app "LogYard" available from Google Play (Android) and App Store (iOS). The study participant simply starts the recording of data from the embedded sensors (accelerometers, gyroscopes, GPS) of the smartphone by pressing "start" on the app. The recording goes on until it is stopped by activating the "stop" button shown on the smartphone screen during recording.

Ways to contribute metadata

Additional information about the recording can be provided by keying in short text messages during the ride, or afterwards to each file containing the recorded information when presented to the user in upload mode. By means of this function, metadata about the recording (road conditions, special events, etc) can be added and made available to the analyst in the analysis. The upload functionality also provide the user with options about which files (i.e. recordings) that should be uploaded and which should be deleted and not made available to the analysis.

Participants' anonymity

The recording of driver movements or behaviour during regular use of any vehicle in order to improve safety might at first be considered unproblematic. However, the experiences from introducing systems that enable postcrash analysis in cars tells us that many car customers are reluctant to such initiatives as it can provide data that may be incriminating to the driver. The use of GPS-information can also be considered sensitive and highly intrusive. Thus, high volume recording of VRUs' movements must comply to *good research practice* and be able to adhere to different levels of anonymity/privacy according to the purpose of the study and the participants' interest.

Three anonymity/privacy levels can easily be discerned:
    i)   No need for anonymity/privacy: This is trivial in the sense that no measures needs to be taken to govern the privacy or anonymity of the participants taking part in the study. However, the validity of data collected under these circumstances may be questioned as participants may choose to leave out information or avoid activities when not acting under the cover of anonymity.
    ii) Complete anonymity/privacy: Although there are many applications where anonymously provided data can be of interest, the design of systems that can ensure complete anonymity based on data provided by smartphones is beyond the scope of this presentation. Even though measures are taken to secure anonymity, we have learned that virtually no system can stand hostile attacks from a resourceful intruder.
    iii) High demands on anonymity/privacy: In the research community, good research practice has established a high level of anonymity that, for all intents and purposes, come close to complete anonymity. This level of anonymity allows research personnel to handle sensitive information from individuals by using individual codes and the link between the code and the actual person (the key) is kept hidden and only available to the person being responsible for the study and act under vow of silence/confidentiality. This means that it is only in exceptional cases where it is in all concerned parties' interest to connect specific data to the actual person, that the key information is used. In a clinical study, for instance, it might be that the analysis has identified a serious condition that needs to be treated.
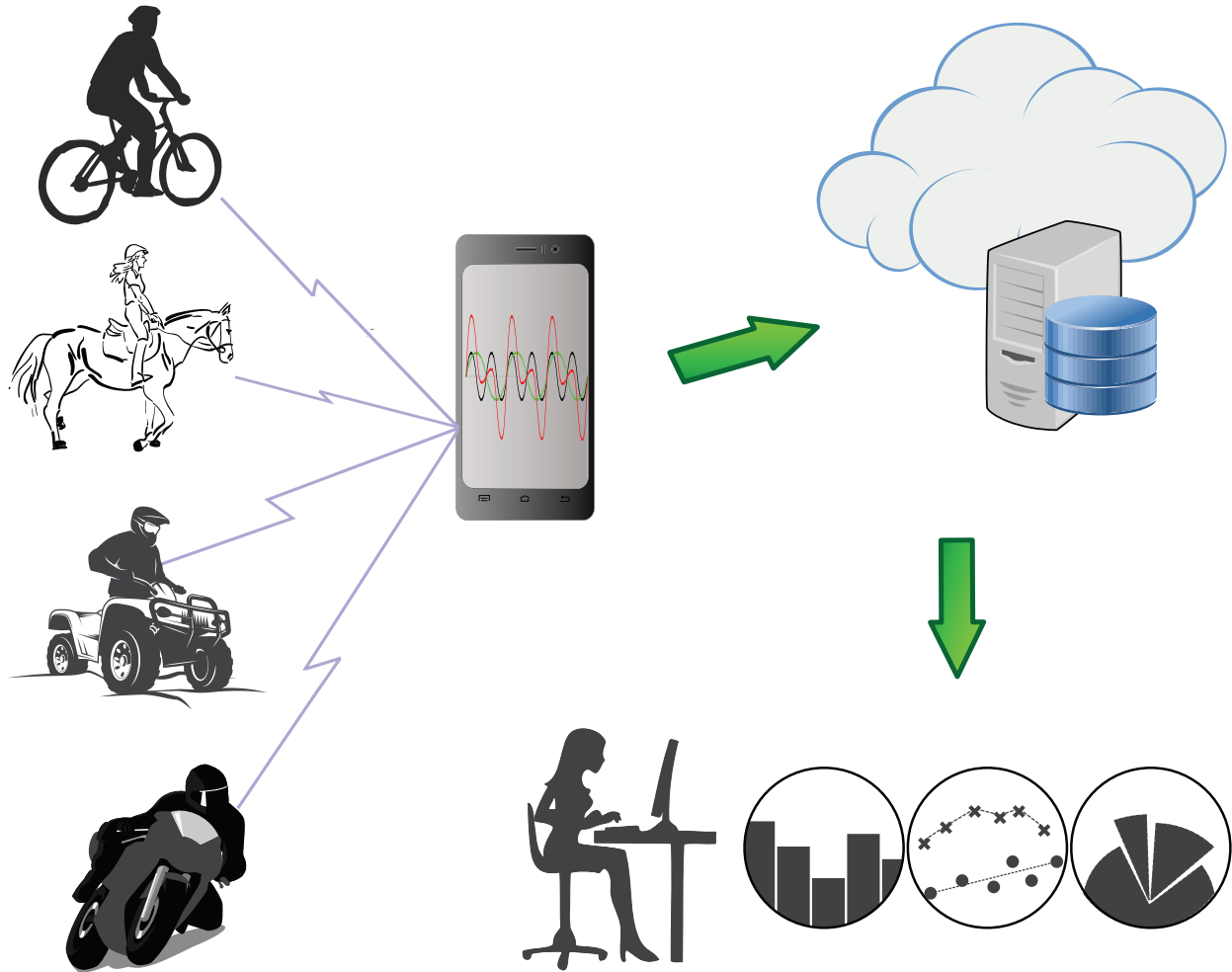
Figure 1: Participants taking part in a study can record movement data (from the smartphone embedded tri-axial accelerometer, gyroscopes and GPS –system) during their everyday transportation/spare time activities (left). The participants upload their activity files of choice to the "cloud". Researchers and other stakeholders associated to a specific study can easily access all the study data and download it for analysis but cannot connect a participants' data to the actual person. Data upload/download is secured via an encrypted file transfer protocol (FTP).

RESULTS

The suggested smartphone based-platform for large-scale recording of VRUs movement data is presented in Figure 1. All information collected from the users can be uploaded to a cloud-based server. The data integrity is provided by means of an individual key that is sent out to each study participant which establish the link to the cloud-based server where the information is organized according to study and participant.

Procedure to establish an "Informed consent" in high-volume data collection

The procedure to establish an individual "informed consent" from a distance to many participants is shown in Figure 2. The start is always to find and send out information to potential participants. This can be done by sending out flyers or posting invitations on the web. Interested and eligible persons are included in the study after signing the "informed consent" document where the study is described and the study candidate is informed about that the

participation in the study is voluntary and the particiapant's right to at any time leave the study without being asked to explain why.

If the informed consent form is not signed in paper, an email response from the study candidate on the outgoing message providing the necessary information from the study coordinator/principal investigator stating that a response saying "I have read the information and confirm participation in the study" is considered as a signed informed consent. The study candidate thereby becomes a study participant. The principal investigator can then send out the study code that the participant should enter in the LogYard app which then is linked to the specific study in future uploads of LogYard data to the cloud-based server while keeping the participant anonymous to the research staff.
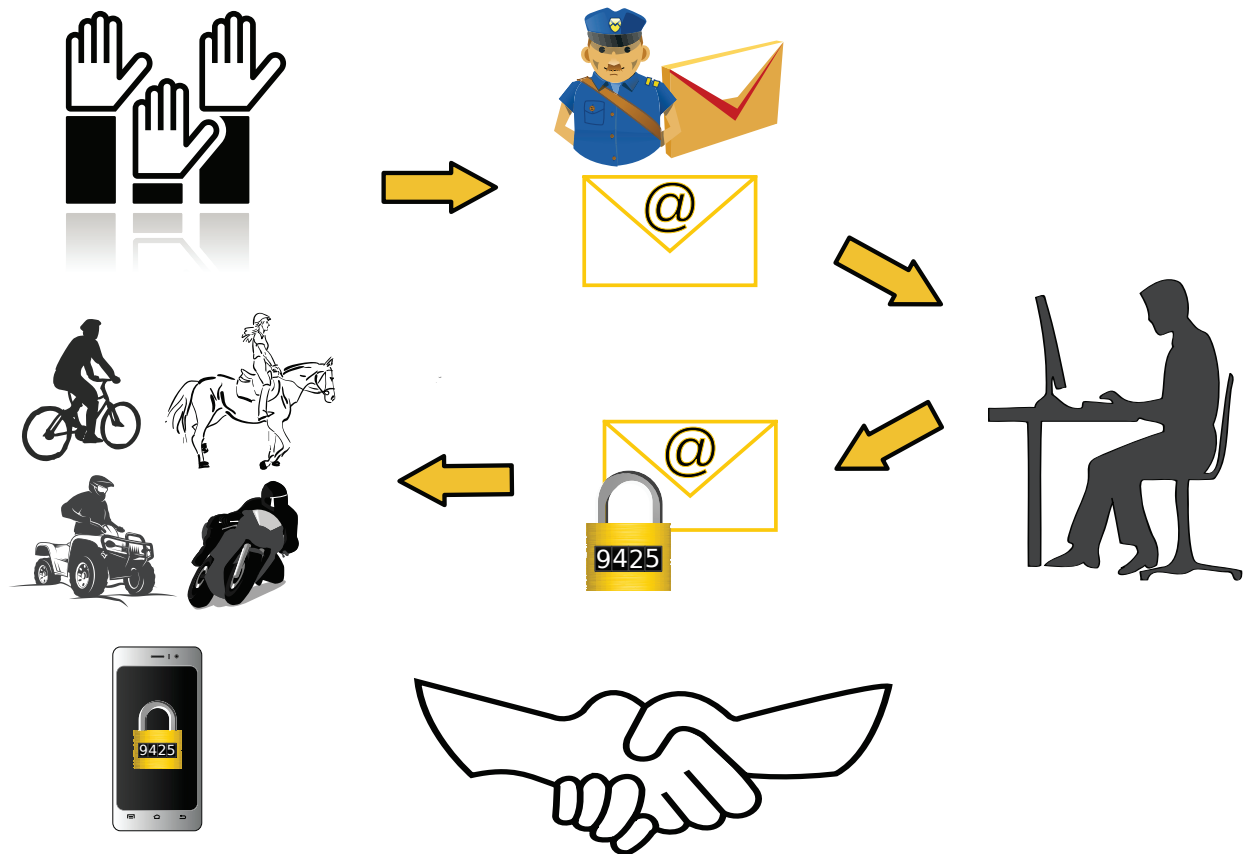

Figure 2: Each participant's privacy is assured according to the procedure shown in the figure. Those that have gotten information about the study and are interested to take part (raised hands) send the signed informed consent form by regular mail (or a corresponding confirmation by email) confirming the will to participate in the study. The principal investigator/person responsible for the study returns the unique study code to the participant. When this code is entered in the smartphone app the link to the cloud-based server is established and the participant can then record and upload data to the study server (as shown in Figure 1). Only the principal investigator knows and has access to the "key" connecting the subject study code to the participating person.

CONCLUSIONS

The infra-structure for large scale, long-term, low-cost smartphone based naturalistic data collection developed in this study can provide large quantities of high quality data from different VRUs use cases and studies. We believe that this information can be used not only to learn about everyday use but also potentially dangerous situations. This information can be used to increase awareness of safer driving behavior based on movement data and the accompanying comments, but also allow automatic crash notification systems for vulnerable road users, similar to the eCall initiative for cars, to be developed.

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